

**MULTIMODE MODEM WITH AUTOMATIC NEGOTIATION
OF OPERATIONAL MODE**

Field of the Invention

5 The present invention relates generally to modems. More particularly, the present invention relates to multimode modems with automatic negotiation of operational mode.

Background of the Invention

10 Secure telephony devices use integral modems to transfer an encrypted digital bitstream representing the user's voice or other data across standard telephone networks. The most widely built and used secure telephone is the STU-III (Secure Terminal Unit, third generation) which was developed for the U.S. Government. A typical STU-III supports data transfers up to 9600 bps, 15 and encodes and encrypts speech using federal-standard voice coders. The STU-III modem complies with a unique signaling plan, known as FSVS-210, which was developed for the National Security Agency.

Commercially available modems, which offer performance well in excess of 9600 bps, are based on standards developed by the International 20 Telecommunication Union (ITU), which are documented in the ITU's V.series recommendations. Commercial modems complying with Recommendations V.32, V.34, and V.90 are the most prevalent.

In certain applications, it is desirable that a single device be able to communicate interchangeably with either a secure modem or a commercial

modem. It is well known, however, that the modem characteristics specified in FSVS-210 for STU-III interoperation are not compatible with the ITU V.series modem. Although a single device could conceivably communicate with both STU-III and ITU V.series modems with a *priori* knowledge of the far-end modem's modes of operation, such a solution is impractical since the characteristics of a far end device usually are not known. It would be advantageous therefore, if a single device could communicate with both STU-III and ITU V.series modems without a *priori* knowledge of whether the far-end modem is a commercial modem or a secure modem, or of the far-end modem's operational mode. Thus, there is a need in the art for a multimode modem that can automatically determine and negotiate operational mode of a far-end modem.

Summary of the Invention

The present invention satisfies these needs in the art by providing apparatus and methods for determining an operational mode of a far-end modem.

Where the multimode modem is a call initiator, a method according to the present invention for identifying a far-end modem type includes transmitting a V.8 ANS_{am} tone to the far-end modem, receiving a response signal from the far-end modem in response to the transmitted V.8 ANS_{am} tone, and determining from the response signal whether the far-end modem is a commercial (e.g., V.series) modem or a secure (e.g., FSVS) modem.

If the response signal is a V.8 CM tone, then the far-end modem is determined to be a V.8 modem. If, on the other hand, the response signal is not a V.8 CM tone, but rather, has a nominal frequency of about 1800 Hz, then the far-end modem can be either a V.32 modem or a secure modem.

If the response signal has a nominal frequency of about 1800 Hz, but does not include phase shifts, then the far-end modem is determined to be a V.32 modem. If, on the other hand, the response signal includes phase shifts, then the far-end modem is determined to be a secure modem.

30 If the far-end modem is determined to be a secure modem, then an

operational mode of the far-end modem can be determined from the response signal. If the response signal includes phase reversals, then the far-end modem is determined to be an FSVS modem in alternate mode. If the response signal includes a 128 dabit gap, then the far-end modem is determined to be an FSVS

- 5 modem in half-duplex mode. If the response signal does not include either phase reversals or a 128 dabit gap, then the far-end modem is determined to be an FSVS modem in interoperable mode.

This invention is possible since a commercial V.series modem is looking for energy at 1800 Hz. Since the transmission of an 1800 Hz tone with

- 10 45-degree phase reversals would violate V.32 specifications (which require a pure 1800 Hz tone), the V.series initiator will ignore the 45 degree phase shifts present in a P1800 Hz tone, and consider the tone to be the expected "AA" tone. Also, the V.series initiator ignores the phase reversals in the "alternate mode" P1800 Hz tone, which occur in the first 80 msec of reply, since it looks for phase
15 reversals only after it transmits "AC", which can occur no sooner than 155 msec after the start of the P1800 Hz tone.

Where the multimode modem is a call responder, a method according to the present invention for identifying a far-end modem type includes transmitting to the far-end modem a P1800 Hz tone with phase reversals,

- 20 receiving a response signal from the far-end modem in response to the transmitted P1800 Hz tone, and determining from the response signal whether the far-end modem is a commercial modem or a secure modem.

An incoming channel is simultaneously monitored for the presence of a V.8 ANS_{am} tone, and for energy at either 1800 Hz or 2100 Hz. If a V.8 ANS_{am}

- 25 tone is present in the incoming channel, then the far-end modem is determined to be a V.8 modem. If 1800 Hz energy is present in the incoming channel for at least about one second, then the far-end modem is determined to be an FSVS modem operating in half-duplex mode. If 2100 Hz energy is present in the incoming channel for at least about one second, then the far-end modem can be
30 either a V.32 modem, or an FSVS modem operating in either interoperable mode

or alternate mode.

If the response signal includes a V.32 AC, then the far-end modem is determined to be a V.32 modem. If, on the other hand, the response signal includes an FSVS Message A, then the far-end modem is determined to be an

- 5 FSVS modem in alternate signaling mode. If the response signal includes neither a V.32 AC nor an FSVS Message A, then the far-end modem is determined to be an FSVS modem in interoperable mode.

Apparatus according to the invention include computer-readable media having stored thereon computer executable instructions for performing any
10 of the inventive methods.

Brief Description of the Drawings

The foregoing summary, as well as the following detailed description of the preferred embodiments, is better understood when read in conjunction with
15 the appended drawings. For the purpose of illustrating the invention, there is shown in the drawings an embodiment that is presently preferred, it being understood, however, that the invention is not limited to the specific apparatus and methods disclosed.

Figure 1 is a flowchart of a method for initiating a call using a
20 multimode modem with automatic negotiation of operational mode.

Figure 2 is a flowchart of a method for responding to a call using a multimode modem with automatic negotiation of operational mode.

Figures 3A-3D depict calling scenarios for an auto-negotiating
25 modem responding to a call from various modem initiators.

Detailed Description of Preferred Embodiments

STU-III Full Duplex Modem Training

A secure STU-III call typically begins from a state where both parties
30 are connected in a non-secure telephone conversation. To transition the call into

a secure call, one of the users activates the security via their STU-III. This STU-III is commonly known as the "security initiator." A full-duplex STU-III initiator will transmit either a 2100 Hz echo suppressor disable (ESD) or a 2100 Hz echo suppressor canceller disable (ESCD) tone. The ESCD tone differs from the ESD tone in that the ESCD tone has phase reversals every 450 msec. Whether the ESD tone or the ESCD tone if used depends on the model of STU-III. Older STU-III's typically provide a strap setting for selecting either ESD or ESCD. Newer STU-III's typically do not include this strap setting, and send only the ESD tone.

- Upon detection of at least 1 second of the received 2100 Hz tone,
- 10 the far-end or responding STU-III (the "security responder") will transmit a pseudo-1800 Hz tone (P1800). The P1800Hz tone is not a pure 1800 HZ sine wave, but rather, it is constructed by alternately transmitting dibits 0 and 2. This generates a tone with an average frequency of 1800 Hz, having alternating positive and negative phase shifts of 45 degrees every baud-time (which is
- 15 typically about 1/1200 sec, or 0.833 msec).

The P1800 Hz tone can be generated either as an "interoperable signaling mode" P1800 Hz tone, or as an "alternate signaling mode" P1800Hz tone. If the responding STU-III supports "alternate mode" signaling, it will transmit three 180 degree phase reversals in the P1800 Hz tone at baud times 32, 64, and

20 96 (26.6, 53.3, and 80 msec, respectively). For "interoperable mode", no phase reversals are included in the P1800Hz tone.

After detecting the responder's P1800 Hz tone, the initiating STU-III will wait 90 msec (108 baud-times), and then terminate transmission of the ESD or ESCD tone. If the responding STU-III transmitted phase reversals in the

25 P1800 Hz tone, and the initiating STU-III also supports "alternate mode" signaling, the initiating STU-III will transmit an FSVS "Message A" 85 msec after termination of the ESD or ESCD tone.

After detecting the initiator's removal of the ESD or ESCD tone, the responder will continue transmitting the P1800Hz for 150 msec (180 baud-times).

30 If the start of Message A is not received by the responding STU-III during this

time, it will transmit 4096 bits of Scrambled Ones (SCR1), followed by silence. This indicates "interoperable mode". If the start of Message A is received during the 150 msec, the responder will reply with an FSVS "Message B" and "alternate mode" signaling begins using training and modulation techniques similar to ITU 5 V.32.

For "interoperable mode" signaling, the initiating STU-III trains its equalizer on the received SCR1, and on completion, the initiator sends the 2100 Hz tone again for 1 second followed by 4096 bits of SCR1, followed by silence. The responding STU-III trains its equalizer on the received SCR1 pattern then 10 transmit 704 bits of SCR1 to indicate its readiness to exchange STU-III signaling messages. These signaling messages and the user data are transferred using modulation techniques similar to ITU-V.26 standards.

Half-duplex STU-III calls can be established by the initiator's transmitting an 1800 Hz tone instead of the 2100 Hz ESD/ESCD. Also, a 15 responding STU-III can force a half-duplex mode by placing gaps in its P1800 Hz response.

V.32 Modem Training.

V.32 modems can use V.8 or V.25 startup to initiate modem training. 20 The V.8 process is described below for V.34/V.90 modems. V.32 modems using V.25 startup initiate modem training by transmitting a 2100 Hz tone with phase reversals. This tone is transmitted from the answer-mode modem, per the V.25 standard, and is referred to as the "ANS" tone. Note that when ITU-V.series modems are used in a secure telephony application, the security initiator is the 25 "answer-mode" modem as defined in the ITU standards.

Upon detecting the ANS tone, the calling mode modem replies to the ANS tone, after one second, with an "AA" pattern. This pattern is a fixed, 1800 Hz sinusoid, without phase shifts or reversals.

After receiving at least 100 msec of the "AA" pattern, the answer - 30 mode modem terminates transmission of the ANS tone, waits 75 msec, and

transmits the "AC" pattern, which is either a 600 Hz or a 3000 Hz signal, for at least 64 baud times (2400 baud/sec), after which it switches to transmitting the "CA" pattern. This switch from "AC" to "CA" results in a 180 degree phase reversal in the answer-mode transmitted signal.

5 Upon detecting the "AC" to "CA" phase reversal, the calling-mode modem delays 64 baud-times, and changes from transmitting "AA" to "CC". This results in 180-degree phase reversal in the 1800 Hz sinusoid.

10 Upon detecting The "AA" to "CC" phase reversal, the answer-mode modem waits 64 baud-times, then switches to transmitting the "AC" pattern again resulting in another phase reversal.

15 The calling mode modem, upon detecting the "CA" to "AC" phase reversal, terminates transmission of the "CC" pattern. The answer-mode modem detects the end of the received "CC" pattern, terminating transmission of "AC", and then begins echo cancellation training.

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V.34/V.90 Modem Training

20 V.34 and V.90 modems always employ V.8 signaling to start a connection. Like V.25, V.8 starts with a 2100 Hz answer tone. In V.8 signaling, however, this answer tone is amplitude modulated at a +/- 20% level by a 15 Hz signal, and is therefore referred to as "ANS_{am}". A V.8-compliant DCE, upon detecting the modulation of the answer tone, will proceed with V.8 signaling, whereby modem capabilities are negotiated before modem training using a 300 bps V.21-based exchange. The allowed modem families that can be negotiated with V.8 include V.22, V.23, V.26, V.27, V.32, V.34, and V.90. After the common 25 modem capabilities are determined, the modem training process begins. If a V.8-compatible modem receives the V.25 ANS tone (with no amplitude modulation), it will transition to V.32/V.32bis mode.

Automatic Modem Negotiation

30 A method according to the invention will now be described for an

auto-negotiating modem that can determine which signaling data link layer modem (STU-III 2400, STU-III 4800/9600, standard V.32, or V.34/V.90) to engage based on the results of modem training. Two scenarios are described: the auto-negotiating modem as the initiator (answer-mode modem), and the auto-

- 5 negotiating modem as the responder (call-mode modem).

Security Initiator

Figure 1 is a flowchart of a method 100 for initiating a call using a multimode modem with automatic negotiation of operational mode. At step 102, the auto-negotiating multi-mode modem initiates full duplex modem training by transmitting an ANS_{am} tone in accordance with V.8 for an answer-mode modem. The initiator waits, at step 104, for a response signal from the responder by starting a 3.3 second timer, in accordance with the V.25 specification, and monitoring the environment, at step 106, for the presence of either of energy at 1800 Hz or a V.8 "CM" pattern.

If, at step 108, the initiator receives the V.8 "CM" pattern, then the far-end modem is identified as being V.8-compatible. If desirable, modem negotiation can then proceed, at step 116, using the V.8 protocol. The initiator replies to the response signal by sending a V.8 "JM" pattern to the far-end modem. Modem training in accordance with the negotiated modem mode is completed, and the appropriate security signaling is performed.

If, at step 110, the initiator detects the presence of energy at 1800 Hz, the initiator identifies the far-end modem as either a secure modem (STU-III), or a V.32 commercial modem. To determine which of these the far-end modem is, additional characteristics of the response signal are determined.

At step 118, the initiator determines whether the received 1800 Hz response signal is a V.32 "AA" by looking for phase shifts in the response signal. If the response signal has no phase shifts, then, after receiving 100 msec of the "AA" pattern, the initiator proceeds, at step 126, with V.32 signaling by transmitting the "AC" pattern to the responder. The initiator continues with V.32

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signaling and training, and uses the appropriate security signaling to complete the secure connection.

- If, at step 118, the initiator determines that the 1800 Hz response signal does include phase shifts of about 45 degrees, then the initiator determines 5 that the response signal is P1800 Hz, and that the responder is a STU-III. If the initiating auto-negotiating multi-mode modem receives a STU-III P1800 Hz tone in response to the ANS_{am} tone it will proceed with STU-III signaling.

To determine the operating mode of the far-end STU-III, the initiator first determines, at step 120, whether the response signal includes phase 10 reversals. If, at step 120, the initiator determines that the response signal is a P1800 Hz signal with phase reversals, then the initiator determines that the responder is a STU-III in alternate mode. At step 128, the initiator completes STU-III alternate mode signaling by terminating the ANS_{am} tone (which appears to the far-end STU-III to be ESCD) 90 msec after detecting P1800 and then 15 transmitting Message A after 85 msec. The initiator then waits for Message B from the responder.

If, at step 120, the initiator determines that the P1800 Hz signal does not include phase reversals, then the initiator determines, at step 122, whether the far-end STU-III is in half-duplex mode or interoperable mode by 20 determining whether a 128 dabit gap is present in the P1800 Hz tone. If the dabit gap is not present, then the initiator determines that the responder is a STU-III in interoperable mode and, at step 124, completes interoperable mode signaling and then waits for SCR1 from the responder.

If, at step 122, the initiator determines that there is a 128 dabit gap in 25 the P1800 Hz tone, then the initiator determines that the responder is a STU-III operating in half-duplex mode and, at step 130, completes half-duplex signaling.

If, at step 112, the initiating auto-negotiating multi-mode modem receives neither a V.8 "CM" nor energy at 1800 HZ in response to the transmitted ANS_{am} tone within approximately 3.3 seconds, it will timeout and, at step 114, 30 indicate a secure connection failure.

An auto-negotiating multi-mode modem, when initiating half-duplex calls, will follow the STU-III half duplex initiation protocol by outputting a P1800 signal instead of a 2100 Hz ESCD tone.

5 Modem Responder

Figure 2 is a flowchart of a method 200 for responding to a call using a multimode modem with automatic negotiation of operational mode. While in a non-secure call, the auto-negotiating multi-mode modem continuously monitors for two signals from the telephone line to which it is coupled: a 2100 Hz

- 10 ESD/ESCD/V.8 tone indicating far-end modem initiation, and a P1800 Hz tone for far-end half-duplex STU-III mode initiation.

If, at step 202, the multimode modem determines that it has received a P1800 Hz for 1024 bit times followed by a gap of 128 dibits, then the responder determines that the initiator is a STU-III in half-duplex mode. At step
15 204, the multimode modem performs STU-III half-duplex signaling in the responder role.

If, at step 206, the multimode modem determines that it has received an amplitude modulated 2100 Hz tone (*i.e.*, an "ANS_{am}" in accordance with V.8), then the responder determines that the initiator is a V.8 modem. At
20 step 208, the responder replies with the V.8 "CM" sequence indicating its available modem types, and continues with modem negotiation in accordance with V.8 (see Figure 3A).

If, at step 210, the multimode modem determines that it has received an ESD/ESCD/ANS tone (*i.e.*, a 2100 Hz tone without amplitude modulation) for one second, then, at step 212, the responder transmits a P1800 tone with phase reversals (the STU-III "alternate mode" signaling response).

While transmitting the P1800 tone, the auto-negotiating multi-mode modern will wait up to 150 msec after detecting a loss of ESD/ESCD/ANS to detect either a V.32 "AC" or a STU-III Message A in response. If the responder
30 detects a loss of ESD/ESCD/ANS at step 214, then the responder starts a 150

msec timer at step 216.

- If, at step 218, the responder detects a V.32 "AC" within the 150 msec window, then the responder determines that the far-end modem is a V.32 modem. At step 220, the responder stops the 150 msec timer, and changes the 5 P1800 Hz transmission to the V.32 "AA." At step 222, the responder proceeds with V.32 training and the appropriate security signaling (see Figure 3B).

- If, at step 224, the responder detects the start of STU-III Message A within the 150 msec window, then the responder determines that the far-end modem is a STU-III modem operating in alternate mode. At step 226, the 10 responder stops the 150 msec timer, and transmits Message B. At step 228, the responder completes STU-III alternate mode signaling (see Figure 3C).

- If, at step 230, the responder determines that it has not detected either a V.32 "AC" response or a STU-III Message A response within the 150 msec window, then the responder determines that the far-end modem is a STU-III 15 modem in interoperable mode. At step 232, the responder transmits the SCR1 and, at step 234, completes STU-III interoperable mode signaling (see Figure 3D).

- The present invention is possible since a commercial V.series modem is looking for energy at 1800 Hz. Since the transmission of an 1800 Hz 20 tone with 45-degree phase reversals would be in violation of V.32 specifications (which require a pure 1800 Hz tone), the V.series initiator will ignore the 45 degree phase shifts present in a P1800 Hz tone, and consider the tone to be the expected "AA" tone. Also, the V.series initiator ignores the phase reversals in the "alternate mode" P1800 Hz tone, which occur in the first 80 msec of reply, since it 25 looks for phase reversals only after it transmits "AC", which can occur no sooner than 155 msec after the start of the P1800 Hz tone.

- In a preferred embodiment, an auto-negotiating, multi-mode modem according to the present invention can be implemented in a digital signal processor (DSP) coupled to a telephone network via analog-to-digital (A/D) and 30 digital-to-analog (D/A) converters and a telephone hybrid. The telephone hybrid

converts the two-wire interface used in analog telephone circuits into separate transmit and receive signals (*i.e.*, four-wire). These four-wire signals are then converted between the analog domain and the digital domain with A/D (for the receive path) and D/A (for the transmit path) converters. The resulting digital

- 5 representation of the analog signals is processed by a DSP. The DSP analyzes received signals to determine frequency and phase information, and generates transmit signals of the proper frequency and phase to convey the appropriate signaling. By analyzing and manipulating the frequency and phase of the signals, the DSP performs a modulator/demodulator (modem) function.

10 To support digital telephone interfaces, like ISDN, the telephone hybrid and D/A and A/D converters are eliminated, and are replaced with an ISDN network interface function. The DSP would then also include a companding function to interface to the A-law or μ -law coding.

The methods of the present invention can be also be implemented
15 in software, and stored as computer-executable instructions on a fixed or removable computer-readable medium, such as a microprocessor, computer hard drive, floppy disk, or the like.

Thus there have been described apparatus and methods for determining an operational mode of a far-end modem. Those skilled in the art will
20 appreciate that numerous changes and modifications may be made to the preferred embodiments of the invention and that such changes and modifications may be made without departing from the spirit of the invention. It is therefore intended that the appended claims cover all such equivalent variations as fall within the true spirit and scope of the invention.